[Name of document] Specification

[Title of invention] Energy absorbing type steering shaft and methods and apparatus for assembling the steering shaft

[Scope of Demand]

[Claim 1]

An energy absorbing type steering shaft, in which an outer shaft is press-fitted around an inner shaft, the steering shaft being characterized in that:

the outer shape of inner shaft has a circular cross section;

the inner shape of outer shaft has a circular cross section and has a diameter that is larger than the diameter of the outer shape of the inner shaft; and

more than three fine members are disposed between the circular cross-sectional outer shape and the circular cross-sectional inner shape, the fine members extending along the axial direction of the inner shaft and the outer shaft to prevent the direct contact of the inner shaft and the outer shaft.

[Claim 2]

An energy absorbing type steering shaft according to claim 1, characterized in that the length of the fine members in the axial direction is longer than a predetermined length that prohibits the direct contact of the inner shaft and the outer shaft while the inner shaft and outer shaft absorb energy and become more deeply fitted.

[Claim 3]

An energy absorbing type steering shaft according to claim 1 or 2, characterized in that the Vickers hardness of the inner shaft and the Vickers hardness of the fine

members differs by at least 200 or the Vickers hardness of outer shaft and the Vickers hardness of the fine members differs by at least 200.

[Claim 4]

An energy absorbing type steering shaft according to claim 1 or 2 or 3, characterized in that the fine member is coupled to an end face of the inner shaft or to an end face of the outer shaft in order to prohibit movement of the fine members in the axial direction.

[Claim 5]

An energy absorbing type steering shaft according to claim 4, comprising means for preventing coupling portions of the fine members from dislodging from the end face of the inner shaft or the end face of the outer shaft.

[Claim 6]

A method for assembling an energy absorbing type steering shaft by press-fitting an outer shaft around an inner shaft, the method being characterized by:

a step of extending more than three fine members along the axial direction of an outer shape of the inner shaft or an inner shape of the outer shaft; and

a step of press-fitting the outer shaft around the inner shaft while prohibiting the direct contact of the inner shaft and the outer shaft by means of more than three fine members.

[Claim 7]

A method according to claim 6, characterized in that at least one of the inner shaft, the outer shaft, or the fine members is deformed beyond an elastic limit thereof during the pressing step.

[Claim 8]

A method according to claim 6 or 7, further characterized by a step of measuring the pressing load being applied during the pressing step, and a step of cutting the fine members when the measured pressing load reaches a predetermined value.

[Claim 9]

A method according to claim 6 or 7, further characterized by a step of extending a predetermined length of more than three fine members along the axial direction of the inner shape of the outer shaft, and a step of press-fitting the outer shaft around the inner shaft while prohibiting the fine members from being axially pulled further.

[Claim 10]

An apparatus for assembling an energy absorbing type steering shaft being characterized by:

a device for press-fitting an outer shaft around an inner shaft; and

a fine member supply device, disposed adjacent to the pressing device, for supplying more than three fine members into a clearance defined between an outer shape of the inner shaft and an inner shape of the outer shaft.

[Detailed description of the invention]

[0001]

[Field of the Invention]

The present invention relates to techniques for readily producing steering shaft having uniform energy absorption performance. Herein, 'uniform' means that variations (in energy absorption performance) from product to product are small.

[0002]

[Description of the Related Art]

Known steering shaft is formed by fitting an inner shaft into an outer shaft. The shafts become more deeply fitted when energy is absorbed. During the manufacture of such energy absorbing type steering shafts, variations in energy absorption performance from product to product within the same lot are required to be very small.

Japanese Unexamined Patent Publication No. 56-8755 and Japanese Unexamined Utility Model Publication No. 56-6669 disclose techniques that address the above-described requirement. These references describe an energy absorption steering shaft, in which an inner shaft is pressed into an outer shaft and a fine member, such as a piano wire, is interleaved between the shafts, thereby minimizing variations in energy absorption performance from product to product.

In a steering shaft, the rigidity of outer and inner shafts should not be too great along the axial direction in order to obtain the required energy absorption performance; however, the rigidity thereof should be sufficiently great in the rotating direction in order to prevent the shafts from rotating relative to each other. In order to satisfy these requirements, the above-described prior art steering shafts ensure satisfactory transmission of torque by pressing an inner shaft having an oval cross section into an outer shaft having inner shape whose cross section is similar to the shape of the inner shaft. These prior art steering devices dispose a single piano wire between the shafts in order to prevent the axial rigidity from varying between products.

[0003]

[Problems to be solved by the invention]

In the above-described prior art steering shafts, the oval cross section of the shaft ensures the transmission of the required torque. Therefore, the inner shaft and the outer shaft contact at least at one point in the cross section. Therefore, energy absorption performance is directly affected by differences in the finish of the outer surface of inner shaft and the inner surface of outer shaft and by the dimensional tolerances of these components. Thus, realization of uniform energy absorption performance is hindered. It is an object of the present invention to realize techniques for setting the energy absorption performance of each product at a predetermined constant level, even if the tolerances of the components and variations in the finishes thereof differ between products.

[0004]

[Means for Solving the Problems]

Energy absorbing type steering shafts according to Claim 1 of the present invention are characterized in that an outer shaft is press-fitted into an inner shaft, the inner shaft having a circular cross-sectional outer shape and the outer shaft having a circular cross-sectional inner shape that is larger in diameter than the inner shaft; and, more than three fine members are disposed between the circular cross-sectional outer shape and the circular cross-sectional inner shape such that the fine members extend along the axial direction of the members and inner shaft does not directly contact outer shaft.

According the above description, pressing the inner shaft into the outer shaft also means pressing the outer shaft into the inner shaft. Both pressing operations are

equivalent and generate the same result.

In the steering shaft of the present invention, because more than three fine members prohibit the inner shaft to directly contact the outer shaft, the dimensional tolerances of the inner shaft and outer shaft and variations in the surface conditions of the members have little effect on energy absorption performance and thus, a robust technique is achieved.

By experimentation, the inventors confirmed that by interleaving more than three fine members between the inner shaft and the outer shaft, both of which have circular cross-sections and thus can easily rotate relative to each other, the inner shaft can be press-fitted within the outer shaft rigidly in the rotating direction and less rigidly along the axial direction so that appropriate energy absorption performance is ensured. A single fine member disposed between the shafts does not provide the same results as a plurality of fine members. That is, pressing the circular cross-sectional inner shaft into the circular cross-sectional outer shaft with a single fine member interleaved therebetween, while maintaining the appropriate rigidity in the axial direction, decreases rigidity in the rotating direction. Thus, sufficient torque transmission is not provided. In order to overcome this problem, prior art shafts have utilized an oval cross-sectional shape, as shown in Japanese Unexamined Patent Publication No. 56-8755 and Japanese Unexamined Utility Model Publication No 56-6669.

Energy absorbing type steering shafts according to the present invention provide energy absorption performance that does not vary from device to device. In addition, the

inner shaft and the outer shaft of each steering shaft are fitted together rigidly in the rotating direction and less rigidly in the axial direction to an appropriate degree. Further, the steering shaft is manufactured from circular cross-sectional shafts at a relatively low cost.

[0005]

In the axial direction of an energy absorbing type steering shaft, each fine member is preferably longer than a length that prohibits the inner shaft to directly contact the outer shaft when the both shafts are absorbing energy, which occurs when the inner shaft is being pressed more deeply into the outer shaft.

When this requirement is satisfied, uniform energy absorption performance, or energy absorption, is achieved when the inner shaft axially displaces relative to the outer shaft.

[0006]

In addition, the difference in Vickers hardness between the inner shaft and each fine member or between the outer shaft and each fine member is preferably more than 200. It does not matter whether the Vickers hardness of fine member is greater or less than the inner shaft and the outer shaft.

This requirement ensures plastic deformation of the shafts or the fine members when the inner shaft is press-fitted into the outer shaft. Accordingly, uniform energy absorption performance is ensured regardless of the manufacturing tolerances of the members.

[0007]

Further, the fine members preferably are fixedly coupled to an end face of the inner shaft or the outer

shaft in order to prohibit movement of the fine members in the axial direction.

When this requirement is satisfied, the inner shaft is securely press-fitted within the outer shaft with the fine members disposed between the shafts. Also, when energy is applied to the steering shaft and the both shafts become more deeply fitted into each other, the fine members are maintained at a constant axial position with respect to either the inner shaft or the outer shaft, thereby ensuring uniform energy absorption performance when energy is absorbed.

[0008]

A pull-in prevention means is preferably provided at a coupling portion of each fine member and the coupling portion is attached to the end face of the inner shaft or the outer shaft. For example, the pull-in prevention means may include a loop in the fine member that prevents the coupling portion from being pulled into the clearance between the shafts.

Because the pull-in prevention means prevents the coupling portion from being pulled into the clearance, energy absorption performance becomes substantially uniform.

[0009]

The invention as described in Claim 6 provides methods for assembling energy absorbing type steering shafts, in which an inner shaft is press-fitted into an outer shaft. The methods are characterized by a step of extending more than three fine members in the axial direction along the outer shape of the inner shaft or along the inner shape of the outer shaft and a step of press-

fitting the inner shaft into the outer shaft with the fine members disposed between the inner shaft and the outer shaft so that the fine members prohibits the direct contact of the inner shaft and the outer shaft.

This method facilitates assembly of steering shafts having uniform energy absorption performance.

[0010]

In the above-described assembling method, at least one of the inner shaft, the outer shaft, or the fine members preferably deforms beyond the respective elastic limit thereof. When one deforms past its elastic limit, or is plastically deformed, the adverse effects of dimensional tolerances of the members decrease, which provides an extremely uniform energy absorption performance.

[0011]

In this method, the load that is applied to press-fit the inner shaft into the outer shaft preferably is measured and the fine members are preferably cut when the measured load reaches a predetermined value.

Thus, by using this method, steering shafts can be reliably assembled so as to have an energy absorption performance that is adjusted to a predetermined value.

[0012]

In the alternative, according to this method, a predetermined length of the fine members may preferably be axially positioned along the inner shape of the outer shaft and the inner shaft may preferably be press-fitted into the outer shaft while preventing the fine members from being axially drawn into the outer shaft.

By using this method, the lengths of the fine members disposed between both shafts can be accurately determined

and steering shafts that provide uniform energy absorption performance can be more easily assembled.

[0013]

The invention as described in Claim 10 relates to an apparatus for assembling steering shafts. The assembling apparatus includes a device that press-fits an outer shaft into an inner shaft and a fine-member supply device that supplies more than three fine members to the clearance between the outer shape of the inner shaft and the inner shape of the outer shaft. The fine-member supply device is disposed adjacent to the press-fitting device.

According to this apparatus, steering shafts having uniform energy absorption performance are easily and efficiently assembled.

[0014]

[Embodiments of the invention]

Embodiments according to the present invention will hereinafter be described with reference to the accompanying drawings. Figs. 1 and 2 schematically show the positional relationship between inner shaft IN, outer shaft OU and fine members W after being fitted within. The outer shape of inner shaft IN has a circular cross section and the inner shape of outer shaft OU also has a circular cross section. The inner diameter of outer shaft OU is larger than the outer diameter of inner shaft IN. When both shafts are fitted together, annular-shaped clearance G is defined between shafts IN and OU. More than three fine members W are fitted within clearance G between shafts IN and OU. The outer diameter of each of fine members W, before being fitted therein, is larger than the width of clearance G, which means that fine members W are squeezed

within clearance G. Fine members W are disposed such that outer shaft OU and inner shaft IN are maintained at coaxial relationship. The inner shaft IN can be either a solid shaft or a cylindrical shaft.

[0015]

Fine members W are less rigid than shafts IN and OU. Each fine member W, which has a circular cross section before being fitted into the clearance (See Fig. 3(A)), is plastically deformed when fitted therein (See Fig. 3(B)). This will become clear by referring to WS in Fig. 3(C). In the alternative, fine members W may be more rigid than shafts IN and OU, in which case the shafts will plastically deform when receiving fine members W. This will also become clear by referring to WH in Fig. 3(C). Depressions are formed within both the portion of the outer wall of shaft IN and the portion of the inner wall of shaft OU that contact a common fine member. Moreover, the portions adjacent to the depressions are distended.

Both shafts IN and OU and fine members W may all have equal rigidity, in which case all these components will plastically deform when fitted together.

[0016]

Fig. 4 shows the relationship between the load applied to each component and its deformation. When deformed beyond its elastic limit, the load becomes constant regardless of the amount of deformation. In the present invention, because at least one of shaft IN, shaft OU, or fine member W is deformed beyond its elastic limit, the components are fitted together using a substantially constant load. In Fig. 4, area D indicates the range of elastic deformation. By fitting the components together

within the elastic range, the fitting load varies. In the present invention, by deforming at least one of the components within the plastic deformation level indicated by area E, the dimensional tolerances of the components are prevented from varying the fitting load.

[0017]

Fig. 5 shows an assembling apparatus according to the first embodiment of the present invention. First column 50B is fixed to base 50A. Jig 50C vertically positions outer shaft OU and is disposed on the upper end of first column 50B. Cylinder 55C is fixed above jig 50C. Cylinder 55C is fixed to first column 50B by a member, which is not shown. Another jig 55A vertically positions inner shaft IN and is disposed at the lower end of piston 55B of cylinder 55C. Outer shaft OU and inner shaft IN are coaxially positioned by respective jigs 50C, 55A. When jig 55A is lowered by cylinder 55C, inner shaft IN is pressed into outer shaft OU. In other words, outer shaft OU is press-fitted around inner shaft IN. In this specification, there is no difference in meaning between these two expressions.

[0018]

Four fine member supply devices 60 are disposed near first column 50B. The fine member supply devices are all identical in structure. Therefore, the following description will be focused on only one.

Fine member supply device 60 includes second column 50D, which is fixed to base 50A. Arms 51A, 51B are mounted on second column 50D via cylinders, which are not shown, so as to be selectively moved upward or downward. Fine member W is wound around drum 51D, which faces side arm 51A and

freely rotates. Three fine members W1, W3, W4 are shown in the drawing and fine member W2 is blocked from view. Hereinafter, reference numerals will be omitted for the description of the common features of fine members W1, W2, W3, W4.

Wrist 51C is disposed at the upper end of arm 51B and can rotate about pin 53. A pair of fine member supply rollers 52 is rotatably mounted on wrist 51C. The pair of rollers 52 is rotated by a motor, which is not shown. Cutter 54 for cutting fine member W is attached to the lower end of wrist 51C.

The assembling apparatus includes a device that press-fits outer shaft OU around inner shaft IN. The assembling apparatus also includes a fine member supply device that supplies fine members W into a clearance defined between the outer shape of inner shaft IN and the inner shape of outer shaft OU and the fine member supply device is adjacent to the pressing device.

[0019]

The operation of the assembling apparatus will now be described. First, outer shaft OU is set on jig 50C. Then, fine member supply rollers 52 rotate a predetermined number of times so as to feed a predetermined length of fine member W. The fed fine member axially extends a predetermined length along the inner face of outer shaft OU. At this time, four fine members W are circumferentially arranged in such a manner as to be equally spaced apart from each other. In this state, each of fine member supply rollers 52 is prevented from rotating. Subsequently, inner shaft IN is held by jig 55A. Thereafter, cylinder 55C is actuated in order to press down

jig 55A. As a result, inner shaft IN is pressed into outer shaft OU and four fine members W are axially disposed at the predetermined distance along the inner face of outer shaft OU. At this time, inner shaft IN does not directly contact outer shaft OU. While inner shaft IN is being pressed into outer shaft OU, each of fine member supply rollers 52 is prohibited from rotating so as to prevent fine members W from being further pulled into outer shaft OU.

[0020]

After inner shaft IN is pressed into outer shaft OU, arms 51A, 51B are lowered in order to bend down fine member W, which extends from the upper face of outer shaft OU. At this time, wrist 51C rotates about pin 53. Cutter 54 cuts bent fine member W at a line that is spaced by a predetermined length from the face of the upper end of outer shaft OU. Then, fine member W, which extends from outer shaft OU, is further bent along outer shaft OU using a tool. This operation will become clear by referring to Fig. 6.

[0021]

In a steering shaft assembled in such a manner, outer shaft OU is press-fitted around inner shaft IN, four fine members W are disposed a predetermined length along the inner shape of outer shaft OU and the four fine members W are prohibited from being axially pulled further into outer shaft OU. Accordingly, fine member W extends between inner shaft IN and outer shaft OU and has been cut at a predetermined length. This feature contributes to ensuring uniform energy absorption performance. Four fine members W separate inner shaft IN and outer shaft OU from each other,

thereby preventing inner shaft IN from directly contacting outer shaft OU. This feature also contributes to ensuring uniform energy absorption performance. After assembling the steering shaft, fine member W remains bent and fixed to the upper end face of outer shaft OU. If energy is applied to both shafts IN and OU so that inner shaft IN is pressed more deeply into outer shaft OU, fine members W will reliably guide inner shaft IN during the pressing operation while remaining fixedly coupled to the upper end face of outer shaft OU. In addition, because fine members W are fixedly coupled to the upper end face of outer shaft OU and are prohibited from moving in the axial direction, the energy absorption performance is uniform when energy is being absorbed. Further, by using a sufficient length of fine member W, shafts IN and OU are maintained in a parallel relationship when inner shaft IN is pressed deeply into the outer shaft OU. This sufficient length also prevents both shafts from bending and thus contacting each other. This feature prevents inner shaft IN from directly contacting outer shaft OU when energy is absorbed. The axial length of fine member W is predetermined in order to prevent inner shaft IN from directly contacting outer shaft OU when inner shaft IN is further pressed into outer shaft OU in order to absorb energy. Accordingly, the energy absorption performance is uniform when energy is absorbed. If three or more fine members are used, the shafts can be maintained in a parallel relationship. Therefore, any number of fine members, not less than three, may be used.

[0022]

Fine member W of the above-described first embodiment is a steel wire that is more rigid than the shafts. The

steel wire is made rigid by being processed. In the present embodiment, each shaft wall that contacts the steel wire is deformed beyond its elastic limit. One shaft is pressed into the other shaft within the range of plastic deformation. Therefore, even if there are variations in the sizes of shafts IN and OU, the variations impart little adverse effect on the assembling load.

The steering shaft according to the present embodiment and the method for assembling steering shafts provide uniform energy absorption performance. Also, the apparatus for assembling steering shafts enables efficient assembling of steering shafts having uniform energy absorption performance.

[0023]

Fiq. 8 shows an assembling apparatus according to a second embodiment of the present invention. The main body of the device is equivalent to the main body of the device shown in Fig. 5. Thus, like elements will be denoted with the same reference numerals and will not be described in detail.

In this assembling apparatus, a bending device, as shown in Fig. 10, is disposed adjacent to wrist 51C. In Fig. 10, reference numerals 58 indicate a pair of gripping pawls, which grips the ends of the fine members, while reference numerals 57 indicate another pair of gripping pawls, which grips the fine members at a position higher than gripping pawls 58. Gripping pawls 58 are selectively turned upward or downward, as shown in Fig. 10(B). Therefore, gripping pawls 58 bend the end of fine member W. Fine member W becomes rigid due to processing. Accordingly, the bent portion becomes rigid.

[0024]

The apparatus of Fig. 8 operates as follows. Outer shaft OU is first set on jig 50C. Then, each of fine member supply rollers 52 is rotated a predetermined number of times in order to feed a predetermined length of fine member W. The fed fine member is aligned with the downward path of inner shaft IN. By lowering inner shaft IN, portions W1A, W2A, W3A, W4A of the ends of the respective fine members are placed into positions in which the respective portions will be fixed to the lower end face of hollow inner shaft IN. In the same manner as the first embodiment, four fine members W are equally spaced apart from each other around the circumference. In this state, a motor freely permits each of fine member supply rollers 52 to rotate. Subsequently, inner shaft IN is set on jig 55B. Cylinder 55C is actuated to press down jig 55B. When jig 55B is pressed down, the bent ends of the four fine members W are fixedly coupled to the lower end face of lowered inner shaft IN. When inner shaft IN is further lowered, fine member W is further pulled out from drum 51D. Inner shaft IN is further pressed down into outer shaft OU with four fine members W interposed therebetween. As inner shaft IN is pressed more deeply into outer shaft OU, more of fine member W is pulled out from drum 51. Upon pressing inner shaft IN to a predetermined depth, cylinder 55C is stopped. Cutter 54A then cuts fine member W on a line near the upper end face of outer shaft OU.

[0025]

In steering shafts assembled with this apparatus, fine member W extends the depth of insertion of inner shaft IN into outer shaft OU. Thus, direct contact of shafts IN

and OU is reliably prohibited. In addition, the lengths of inner shaft IN and outer shaft OU are predetermined so that shafts IN and OUT do not bend. This feature prevents both shafts from bending and contacting each other when the shafts are absorbing energy.

When inner shaft IN is inserted more deeply into outer shaft OU, fine member W becomes fixedly coupled to the lower end of inner shaft IN. Thus, fine member W is prevented from axially displacing with respect to inner shaft IN, and as a result, the lower end of inner shaft IN does not directly contact the inner face of outer shaft OU. By fixedly coupling fine member W to the lower end face of inner shaft IN, movement of fine member W in the axial direction is prohibited with respect to inner shaft IN, thereby making the energy absorption performance of steering shafts assembled using this apparatus substantially uniform.

[0026]

A number of experiments were conducted by the inventors, which show that the energy absorption performance can be made substantially uniform by using fine members W having a Vickers hardness that is at least 200 greater than the material of the shafts. This point will become clear by referring to Fig. 11.

In Fig. 11, the load required to press inner shaft IN into outer shaft OU at a constant speed is indicated by the vertical axis while the pressing depth is indicated by the horizontal axis. The straight thick solid line indicates the results of experiments using a fine member having a Vickers hardness that is 200 greater than the shafts. The bent thin line indicates the results of experiments using a

fine member having a Vickers hardness that is 100 greater than the shafts. If the Vickers hardness of the fine member is 200 greater than the shafts, the pressing load linearly increases with the pressing depth. An unsatisfactory difference in Vickers hardness between the fine member and the shafts results in an irregular relationship between the pressing load and the pressing depth. The inventors found through experimentation that control of the pressing depth ensures accurate control of the pressing load as long as the difference in Vickers hardness is at least 200.

The experiments also show that a fine member made of material having a Vickers hardness that is at least 200 less than the shaft member material also ensures a linear relationship between the pressing depth and the pressing load. Accordingly, when the difference in Vickers hardness between inner shaft IN and fine member W, or between outer shaft OU and fine member W, is at least 200, energy absorption is extremely uniform.

[0027]

Fig. 12 shows an assembling apparatus according to the third embodiment of the present invention. The assembling apparatus of the third embodiment is similar to the assembling apparatus of Fig. 8. Therefore, only different features will now be discussed. In the assembling apparatus, jig 55B includes load cell 55D in order to measure the required pressing load. The assembling apparatus performs the assembly while measuring the pressing load. Fine member W is cut when the pressing load reaches a predetermined value.

Fig. 13 schematically shows the relationship between

the pressing depth and the pressing load. Reference mark A indicates the relationship between the pressing depth and the pressing load for product A. Reference mark B indicates the relationship between the pressing depth and the pressing load for product B that was manufactured according to the same dimensional specification as product A. As was described above, the present invention reduces the effects of differences in dimensional tolerances of the components on the pressing load, which contributes to making the pressing load uniform. As a result, products A and B are substantially similar to each other as compared to prior art products. Fig. 13 shows a large difference between products A and B only for the purpose of illustration. However, the above discussion does not mean that the dimensional tolerances of the components will not have any effect on the pressing load. According to precise measurements, the pressing load varies from product to product. The apparatus of Fig. 12 measures the pressing load using load cell 55D while continuing to press at the constant speed. The apparatus then cuts fine member W when the measured pressing load reaches a predetermined value. Thereafter, the apparatus keeps the pressing load constant when inner shaft IN is further pressed. Consequently, all the products are adjusted to the predetermined pressing load. By utilizing such features in the assembling apparatus, in which one shaft is pressed into the other shaft while the pressing load is measured, and then fine member W is cut when the pressing load reaches the predetermined value, a batch of steering shafts can be assembled with high efficiency and differences in energy absorption performance between the products also can be

minimized.

[0028]

The above-described assembling apparatus includes a step of extending more than three fine members W along the axial direction of the outer shape of inner shaft IN (see Figs. 8 and 12) or the inner shape of outer shaft (see Fig. 5) and a step of press-fitting outer shaft OU around inner shaft IN while prohibiting inner shaft IN from directly contacting outer shaft OU by means of fine members W, thereby assembling a batch of steering shafts having uniform energy absorption performance.

[0029]

Each of the fine members employed in the illustrated embodiments is wound around the drum. However, in the present invention, pre-formed fine members may instead be disposed between inner shaft IN and outer shaft OU. Figs. 14 through 21 show examples of pre-formed fine members.

[0030]

With reference to Fig. 14, first fine member W1, second fine member W2, and connection WT, which form a pair of fine members, are made from a single piece of material. In this case, two pairs are used. The other pair includes third fine member W3 and fourth fine member W4. Each connection WT is positioned on the inner end of inner shaft IN and then inner shaft IN is pressed into outer shaft OU, or outer shaft OU is press-fitted around inner shaft IN.

[0031]

The cross section of fine member W may be circular, because this shape can be formed most inexpensively. However, when it is necessary to fit together the components such that the rigidity in the axial direction is

low and the rigidity in the rotating direction is high, a variety of cross-sectional shapes can be used, as shown in Fig. 15. The fine member is not required to be solid, but also may be hollow.

[0032]

Fig. 16(A) shows examples of fine members fixedly coupled to the end face of outer shaft OU, in which fine members W1, W2 are disposed along the inner face of outer shaft OU in the axial direction. Fine members W are connected together by connections Wf, Wc. Bent portions Wa, Wd are fixedly coupled to the end of outer shaft OU in order to prohibit axial movement of the fine members. Fig. 16(B) shows another example of pre-formed fine members, in which fine members W1, W2, W3, W4 are formed from a single piece of material.

[0033]

Fig. 17(A) shows another example of a pair of pre-formed fine members, in which fine members W1, W2 have different diameters. As shown in Fig. 17(B), this type of fine member is used in two pairs. Thus, inner shaft IN having an oval cross-sectional outer shape may be pressed into outer shaft OU having a circular cross-sectional inner shape, or inner shaft IN having a circular cross-sectional outer shape may be pressed into outer shaft OU having an oval cross-sectional inner shape.

Fig. 17(C) shows another example of a pair of pre-formed fine members, in which the cross-sectional shapes of the fine members are different from each other. Thus, a circular cross-sectional shaft may be fitted into an oval cross-sectional shaft, as shown in Fig. 17(D).

[0034]

Fig. 18(A) shows another example of a pair of pre-formed fine members, in which fine members W1, W2 have different cross-sectional shapes and the cross-sectional shapes gradually change along with the length of the fine member. This type of fine member may be suitably used in order to modify the energy absorption properties when energy is absorbed.

[0035]

If many fine members are used, the fine members may be fixedly coupled to the shaft end face one by one, as shown in Fig. 18(D). However, the fine members may instead be arranged in advance and coupled to the shaft end face all at once, as shown in Fig. 18(E).

[0036]

The inventors also discovered through experimentation that a coupling portion, which couples a fine member to a shaft end face, may be pulled into the clearance between the shafts. This phenomenon will cause a sudden increase in the pressing load, which results in unsatisfactory energy absorption performance.

Fig. 19 through Fig. 21 show examples of pull-in prevention means provided for the coupling portions. Fig. 19(A) shows a catch portion A1 and Fig. 19(B) shows a loose portion B1. In Figs. 19(C) and (D), connections C1, C2, D1 are provided to prevent this phenomenon. In Figs. 19(E) and (F), loops E1 and knots F1, respectively, are shown.

As shown in Fig. 19(D), the lengths of fine members may be different from each other in order to impart anisotropy, in which overlapping portions of the fitted shafts are resistant to bending along the direction of long fine member L1, but tend to bend along the direction of

short fine member L2. In the alternative, interspaces between adjacent fine members may be different from each other, as shown in Fig. 19(C), in order to impart anisotropy, in which overlapping portions of the fitted shafts are resistant to bending along the direction of the narrowly spaced fine members, but tend to bend along the direction of the widely spaced fine members.

[0037]

Fig. 20 shows additional examples of pull-in prevention means. In Figs. 20(A) and (B), projecting portions A1 and looped portions B1, respectively, are shown. In Fig. 20(C), connection CT includes spiral portion C1. In Fig. 20(D), other members D1, D2, D3 are threaded on fine members. Figs. 20(E) and (F) respectively show loops E1, F1. In Fig. 20(G), loops G1 are welded.

[0038]

With reference to Fig. 21, an end face of an outer shaft is processed to form a pull-in prevention means. As shown in Figs. 21(A) and (B), grooves for respectively receiving the fine members are formed in the end face of the outer shaft in order to prevent the coupling portions from being pulled into the outer shaft. Referring to Fig. 21(C), the bottom of each groove is inwardly inclined and the outer edge of the outer shaft defines an acute angle. This feature also prevents the coupling portions from being pulled into the outer shaft. Accordingly, an acute angle formed between the end face of the outer shaft and the side thereof (or if an inner shaft is cylindrical-shaped, an acute angle formed between the end face of the inner shaft and the side thereof) provides the pull-in prevention effect. In addition, as shown in Fig. 21(D), this feature

eliminates the need for a connection on the outer face of the outer shaft(or on the inner face of the inner shaft). Fig. 21(D) shows acute inner edges of the outer shaft, which are examples of pull-in prevention means.

[0039]

While the preferred embodiments of the present invention have been described, such description is for illustrative purposes only, and it is to be understood that changes and variations may be made without departing from the spirit or scope of the accompanying claims.

For example, the following is one preferred modification. Fine members may extend along the length of the overlapping portions of the fitted inner and outer shafts, thereby making the energy absorption performance substantially uniform.

Angular cross-sectional fine members tend to cause stress concentration and introduce plastic deformation. Accordingly, the dimensional tolerances of the components are absorbed and energy absorbing performance is made uniform. Hollow fine members also tend to cause plastic deformation and adverse effects of the dimensional tolerances of the components are accordingly reduced.

In addition, by modifying the circumferential interspaces between adjacent fine members, rigidity can be modified as desired. Thus, axial rigidity can be adjusted. Further, even if, e.g., a weld bead remains on a circular outer tube, the fine members can be disposed so as to avoid the weld bead. This feature facilitates simple post-processing of weld beads.

Lubricant can be applied to the fine members or either one of the shafts to prevent the fine members from

being pulled off when one shaft is pressed into the other shaft.

[Effect of the Invention]

The invention of claim 1 enables the production of steering shafts in which a relatively low-cost, circular cross-sectional inner shaft member is connected to a relatively low-cost, circular cross-sectional outer shaft member less rigidly to a proper degree in the axial direction and rigidly in the rotating direction. Thus, energy absorbing type steering shafts can be manufactured at relatively low cost. In addition, a batch of energy absorption type steering shafts can provide uniform energy absorption performance. By changing the number, the quality, the thickness, etc., of the fine members, various types of energy absorption performance can be provided.

The improvements according to claims 2 through 4 enable uniform energy absorption performance for a batch of energy absorbing type steering shafts.

The assembling method according to claim 6 enables reliable assembly of a batch of steering shafts having uniform energy absorption performance.

The improvements according to claims 7 to 9 further enable uniform energy absorption performance for a batch of energy absorbing type steering shafts.

The assembling apparatus according to claim 10 enables highly efficient assembly of a batch of steering shafts having uniform energy absorption performance.

[BRIEF DESCRIPTION OF THE DRAWINGS]

Fig. 1 schematically shows a steering shaft of the present invention.

Fig. 2 is a cross-sectional view taken along line II-

II shown in Fig. 1.

Figs. 3(A), (B), and (C) show fine members before and after the steering shaft is assembled.

Fig. 4 is a graph showing a relationship between material deformation and load.

Fig 5 shows an assembling apparatus according to a first embodiment.

Fig. 6 is a cross-sectional view of a fitted portion of a steering shaft assembled by the apparatus of Fig. 5.

Fig. 7 is a cross-sectional view taken along line VII-VII in Fig. 6.

Fig. 8 shows an assembling apparatus according to a second embodiment.

Fig. 9 is a cross-sectional view of a fitted portion of a steering shaft assembled by the apparatus of Fig. 8.

Fig. 10 shows a bending mechanism incorporated into the apparatus of Fig. 8.

Fig. 11 is a graph showing a relationship between pressing depth and load.

Fig. 12 shows an assembling apparatus according to a third embodiment.

Fig. 13 is a graph showing a relationship between pressing depth and load.

Fig. 14 shows examples of fine members.

Fig. 15 shows examples of the cross section of the fine members.

Figs. 16(A) and (B) show two examples of the fine members.

Figs. 17(A), (B), (C), and (D) show another two examples of the fine members.

Figs. 18(A), (B), (C), (D) and (E) show further

examples of the fine members.

Figs. 19(A), (B), (C), (D), (E), and (F) show further examples of fine members.

Figs. 20(A), (B), (C), (D), (E), (F), and (G) show further examples of fine members.

Figs. 21(A), (B), (C), and (D) show the relationships between the fine members and the end face of the shaft.

[Description of Numerals]

IN : Inner shaft

OU : Outer shaft

W : Fine member